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ABSTRACT

Technology is changing the classroom requiring new design features and considerations to make the classroom flexible and interactive with the teaching process. The design of a Master Classroom, a product of the Classroom Improvement Project at the University of North Carolina at Chapel Hill, is described. These classrooms are specially-equipped to provide a wide range of computer, media, projection, communications, and control capabilities, including connection to the campus network for both video and data reception and transmission. Topics on Master Classroom development include creating an interactive information environment, equipping the classroom with computer and projection equipment, and designing integrated control systems for the classroom. Focus is given to projection equipment acquisition and the variables involved when deciding the types of equipment to buy, such as brightness, rear or front projection design, screens available, CRT vs. LCD displays, and displays for smaller classrooms. Tips are given on networking information sources to fully utilize the Master Classroom's capabilities and the cost considerations. (Contains 10 references.) (GR)

Master Classrooms: Classroom Design with Technology in Mind

by Kathryn Conway

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What Should a Classroom Be?

The design of a teaching/learning environment suggests assumptions about the teaching and learning process. When you walk into a classroom with only the basic blackboard and, possibly, sound amplification, the assumption is clear: you can teach whatever concepts and provide whatever information is necessary with the lecture, chalkboard and discussion. Master classrooms take a different starting point. They begin with the assumption that different teachers may prefer different teaching styles, that different concepts may require different media and methods of communication, and that different learners have different cognitive styles.

The fact that technology provides these different communication modes does not, however, mean the 'live and real-time' teacher is not the driving force in the classroom. Indeed, the teacher determines the course content and strategy, and is the most spontaneous and valuable instrument in the learner assessment

process. Technology in the classroom should not hinder, but help, teachers who "rely heavily on improvisation, on freedom to follow up ideas that excite interest, and on unexpected happenings that illustrate the problems we discuss . . . Learning technologies should be designed to increase and not reduce the amount of personal contact between faculty and students on intellectual issues." (NIE quoted in Glick, 1990)

As Milton Glick pointed out in his article in EDUCOM Review: "Everything we are used to -- books, lectures, television -- is one-way, focused on what the teacher, writer or actor does. It is hard for us to remember that it is not what the teacher does but what he or she gets students to do that results in learning." (Glick, 1990) For this reason, "interactive computing . . . a new teaching medium, combining visual values of television and instructional ideas," (Hale, 1989) needs to take its place in the classroom.

An interactive teaching process connotes process. But most of our teaching communication and technology to this point has relied more on information products than on information process. It is information technology's ability to bring process into the classroom that is most promising. Garrett, Dominguez and Noblitt illustrate the importance of process in teaching foreign languages: "Our exploration of the role of technology in teaching such courses suggested that one of the most significant innovations is the presentation to the learner of the authentic data of the discipline . . . the computer and interactive technologies can bring the primary and supporting data of the discipline within the grasp of the researcher and the learner alike . . . they can also make the primary data directly available to students, give them the opportunity to browse and explore, and structure an environment within which they can organize and interpret the data for themselves. Knowledge so acquired is not a set of items or facts but is a process, a way of thinking or making connections, a dynamic flexible structure of relationships." (Garrett, Dominguez and Noblitt, 1989) Clearly, these capabilities so central to the teaching and learning process belong in the classroom, and, hopefully, within easy command of the teacher.

The classroom, then, should be a very flexible environment, with the means to present information in a variety of ways, with access to varied information sources, and with maximum flexibility for interaction between and among teacher, student and information. In short, classrooms should be designed to provide interactive teaching and learning environments. To achieve maximum flexibility, these facilities must combine computing, display and networking elements. Because of the range of technologies included, they can also provide a technological bridge between traditional analog/one-way technologies and evolving digital/interactive technologies for classroom instruction. This is what we designed the master classroom to accomplish.

English: Presentation of Composition Concepts. *For several semesters, Professors Richard Rust and James Thompson have taught English composition using a computer in a master classroom. Professor Rust found that projecting a computer screen in the classroom provided a "highly productive way to use classroom time in teaching students various strategies and styles possible in writing and ways to revise their work successfully." Professor Thompson found that the ability to copy text fragments quickly and use a split screen with before-and-after views allowed the class to make immediate comparisons of alternative structures. The result was an emphasis on the revision process rather than on original faults. (Hazen and Parker, 1989)*

What is a Master Classroom?

The Classroom Technologies Service Center (now part of the User Services group within the Office of Information Technology) created the first master classroom at the University of North Carolina at Chapel Hill (UNC-CH) in 1987. We currently provide 14 master classrooms serving a variety of class sizes and curricula. Master classrooms grew out of the Classroom Improvement Project, started several years earlier, and represented a strategic shift to viewing the classroom as an important part of the information

environment on campus. Our version of the master classroom is an outgrowth of expressed faculty need and fiscal constraints requiring a very cost-effective implementation.

Master classrooms are specially-equipped classrooms providing a wide range of computer, media, projection, communications and control capabilities, including connection to the campus network for both video and data reception and transmission. The master classroom is different from a computer classroom or laboratory in that it does not have individual computers for each student, but rather has a single computer on a choice of operating systems that can be used by either a teacher or student(s) for presentations, simulations, on-line access, multimedia, etc. Each master classroom contains two microcomputers for instructional purposes, one operating on MS-DOS with Microsoft Windows and the other on a Macintosh platform. Because both computing platforms are supported by our User Services group and are used across departments and schools on campus, we support both in the classroom. Both microcomputers are connected via the campus network to the computer lab fileservers.

Computer projection capabilities are provided by ceiling-mounted multiscan video projection systems. These same video projectors display the output from video channels on the campus network, and from in-classroom or remotely-located videocassette players or videodisc players. The room also contains a 16mm film projector, a slide projector and an overhead transparency projector. When the room size necessitates it, we provide an audio amplification system.

Creating an Interactive Information Environment

On the surface, a master classroom is not much different from a media classroom containing the traditional overhead transparency, slide and film projectors along with videotape playback and projection. If you look at the microcomputer as a more complex means of displaying information, it's just another point on the evolutionary continuum of instructional technologies. But when you tie the computer and the classroom into campus, state and national data and video networks, the classroom becomes an extended information environment for teaching.

The teacher has real-time access to text and multimedia databases, courseware, software tools of all sorts, simulations, supercomputers, on-line services, electronic mail -- any resource accessible over campus and regional data networks -- as well as Internet, and soon, NREN (the National Research and Education Network). The teacher can also receive live instructional events -- workshops, satellite teleconferences, foreign language newscasts, teleconferencing "visiting" lecturers -- as well as the more traditional film and video materials via the campus network video channels connecting our campus to video feeds from both on and off campus.

Thus, the real power of the master classroom comes from its ability to provide an interactive information environment. This environment gives the faculty the ability to access and manipulate not just information products (such as text, graphics, video), but information processes as well. This "process" capability comes from the synergy created by combining multiple media; the computer's intelligence, speed and processing; network access and 'universal' display capabilities (i.e., both computer and video).

Economics: Presentation of Modeling. *Professor Michael Salemi uses a master classroom to teach advanced topics in macroeconomics. Students are assigned simulation problems using Fair Model, an educational version of a commercial economic modeling software program. Student assignments begin with structured exercises, such as determining the effects of raising taxes on consumption. Later group assignments include more structured applications, such as developing strategies for lowering the federal deficit while minimizing social impact. In class, Professor Salemi runs the same software to discuss issues raised by student exercises and to quickly test conjectures raised in class discussions. (Hazen and Parker, 1989)*

Building Your Own

Designing a master classroom, like designing any other physical space, requires considering many different elements of room function. These include the following:

- Furniture: Fixed or movable, seating capacity, arrangement.
- Heating, cooling and ventilation: Adequate air handling capacity for size and capacity of room and installed equipment.
- Power supply and distribution: Sufficient circuits and power to operate the equipment, functional placement of outlets for equipment.
- Lighting control: Audiovisual blinds or blackout shades, dimmable lighting.
- Acoustical treatment and/or audio reinforcement.
- Equipment control system/user interface.
- Security measures.
- Equipment: Hardware and firmware necessary for software use.

Among these considerations, there are many variables affecting the physical design or renovation, depending on the available space -- its size, location, configuration, age, etc. If you or your staff are not comfortable determining the requirements for the physical renovations, you may want to consult your physical plant staff or other personnel familiar with such renovations. This document focuses on the equipment components of the information management system in the classroom.

Equipment

Table 1 lists the equipment in a master classroom at UNC-CH. The actual placement of the film, slide and overhead projectors in the classroom is optional and depends on your intended use of the room, whether you have the ability to deliver film and video material to the classroom from another site, and whether you can provide the functional equivalent with your computer (i.e. computer multimedia). Faculty should be able to directly control the film, video and slide equipment on demand, whether it is located in the room or at a remote site.

Fixed vs. Portable Equipment

All of our master classrooms at UNC-CH are fixed installations. Some schools may wish to provide the same master classroom capabilities on a movable cart. Whether your master classroom equipment is fixed or movable, don't overlook the critical importance of providing network access to your classrooms.

If you neglect providing network connections to the classrooms in which you use portable equipment, you have diminished the power and usefulness of the technology you are providing. Network connectivity is the single most important factor for the present and future use of technology in your classroom, and the most critical element in creating an interactive information environment.

Providing equipment in a classroom without network access is like providing a telephone handset without the connecting network: it has limited utility and can't serve it's full purpose. So, regardless of your choice of fixed or portable installations, provide network access to the rooms for which you plan master classroom use.

The primary reason we chose fixed installations is that the courses scheduled into the master classrooms use the technology so frequently that it is much easier to leave the equipment configured and in place than it is to move it around. While we still move around individual pieces of equipment, such as an overhead

projector, slide projector or the like for an occasional class that must meet in a room that is not already equipped, we don't move around equipment from the master classroom piecemeal. We have a small collection of movable equipment for that purpose. The master classroom equipment stays put unless it is replaced or removed for repair.

Whether your equipment is configured to be fixed or movable likely depends on three variables: available budget, room scheduling and support arrangements. Some schools may not have sufficient funds to equip multiple classrooms or may want to "try out" the technology in several different curricula. Installing equipment in one classroom is still an option if you can work out arrangements to schedule the courses requiring technology support into your master classroom. This is often easier where there is centralized scheduling of classrooms and you can work out suitable arrangements between those who schedule the classrooms and those who support them. Support arrangements vary, often in the same patterns that scheduling authority varies. That is, if your campus has decentralized scheduling of classrooms, it will probably have decentralized support staff for classrooms.

Setting up centrally scheduled and supported classrooms on a campus in which classrooms are scheduled internally by departments or schools (i.e., decentralized scheduling) can be challenging administratively. On our campus, we were fortunate to have the cooperation of the Classroom Scheduling Office, a central scheduling office operated out of the Registrar's Office, in designating, implementing and scheduling certain classrooms as master classrooms. Master classrooms do not have to be pulled out of the central scheduling routines, since any time not used for technology-intensive courses can be scheduled for a "regular" lecture-style course. In practice, the master classrooms are used more than 80 percent of the time for technology-intensive courses. However, sometimes we have to schedule a room on the basis of seating capacity (it may be the only room that will seat 450 students), handicapped access or some other factor. It has been useful to our Classroom Scheduling Office that these master classrooms provide flexibility in scheduling.

The major scheduling difference is that we require additional information before we will schedule a course into a master classroom. That information consists of the type of capabilities and estimated use of each capability the course requires. If the course requires projection for every class session, but only the overhead transparency projector is being used, we can easily schedule that course in another room equipped with an overhead transparency projector, but without the additional equipment in a master classroom. That way we get maximum return on our investment in the more expensive and powerful equipment in the master classroom. [In addition to our master classrooms, we have over 30 other classrooms that are equipped with a variety of equipment, but that do not include the full range of capabilities of the master classrooms. We call these classrooms "media-intensive" classrooms and they are also scheduled by the Classroom Scheduling Office.]

Movable systems may be more practical if you have to use the equipment in many different rooms because you can't move the courses and/or you have funds for only one or a few installations. In this case you are likely to be moving various components of the master classroom around, rather than the entire complement of equipment listed in Table 1. Because most schools already have the typical audiovisual equipment available, you may want to outfit a cart with only the computer, projection, network connectors, audio and videodisc components. There is a definite advantage to using an LCD panel (with accompanying overhead projector) in this application. The larger video projection devices are heavier, bulkier, take more time to configure, and may cost more than the LCD panels.

Again, if you neglect providing network connections to the classrooms in which you use portable equipment, you have diminished the power and usefulness of the technology you are providing.

Choosing Computer and Projection Equipment

The choice of which computer(s) you use is highly situational. At UNC-CH we chose to provide both an MS-DOS and a Macintosh machine because the User Services group supports use of both platforms and both are used by faculty for their own scholarly and instructional work. Regardless of other factors, the computer you provide must be able to run the software your faculty wish to use in their classes. If you know beforehand which faculty members are likely to use your master classroom, you should check with them to see what kind of software they wish to use and what requirements it makes of the computer system.

For our general purpose classrooms (those used by many different departments and schools) we provide basic software -- operating systems, communications, word processing, spreadsheet, etc. Highly specialized curricular software for these classrooms must be provided by the department. Our support personnel will install the software on the classroom computer or on a server, as long as there is an appropriate license for the use of the software and it is compatible with our servers and network operation.

Communications Capabilities

By connecting your master classroom to existing local area networks and the campus network, you can leverage the software you already have available on your computer lab, other classroom, and departmental servers. That way you reduce your hard disk requirements for the master classroom computer and still have access to a wide variety of software. This also simplifies installations and updates for software because it can all be done on one or two servers rather than on multiple individual machines.

To facilitate your faculty's use of the networking access and capabilities of your classroom, you'll want to provide some easy-to-use communications software. Table 2 lists some typical software we provide in our master classrooms. For the PC, Novell's LAN Workplace provides Windows capability, Telnet and TN3270 emulation for mainframe access. Telnet is freeware from the National Center for Supercomputing Applications that provides network connections to almost any type of computer for line mode operations. This provides text in ASCII character mode, but no graphics. We have added PC WAIS to provide access to Wide Area Information Servers (WAIS). WAIS servers are "smart" servers that can find information without your having to specify the location of the information or give commands to the remote operating system housing the information. With WAIS servers you specify only the type of information you need and the WAIS server searches all the databases connected to it for relevant information. You can then either view or download the information, depending on restrictions that may have been placed on the information.

For the Macintosh, these capabilities are provided separately by NCSA Telnet 2.5 (currently), Hyper FTP (for executing file transfers), Mac X and Mac WAIS. The Mac X software enables the Mac to access other machines, such as UNIX-based computers, supercomputers, mainframes, etc. while still maintaining the graphical user interface of the Macintosh. We sometimes use Mac X in the classroom to access UNIX workstations in faculty offices or other locations. This gives us the ability to project larger machine output without incurring the higher cost of installing a workstation and correspondingly more expensive projection systems in the classroom.

If you don't know specifically which teachers will use the facility, you may want to survey your faculty to see what computers they are using and what word processing, spreadsheet, presentation, multimedia and research analysis software predominates. (Often faculty will want to use the same software they use in their research projects to demonstrate the same or similar processes or concepts in the classroom.) You can also use the survey to get an idea of what instructional software the faculty are using or would like to use.

In evaluating your computer requirements you should consider the following:

- How much memory do your programs require?
- What graphics adapters, video cards or audio cards are required?
- Will software be provided from a diskette, a machine-resident hard disk, a CD-ROM, or remotely accessed from a file server over a network?
- Will video be digital or analog? If digital video is required, will it be hardware-based (DVI) or software-based (Video for Windows, Quicktime, etc.)
- If videodiscs are to be used, do you have the appropriate cards?
- What type of network connection do you require?
- Will media requirements be provided from traditional means (slide, film, video) or from computer-based digital multimedia?

IBM, Apple and other vendors now provide machines which incorporate many of these features in one "bundle." For example, their multimedia models include a CD-ROM, appropriate video and audio cards, and provision for either software- or hardware-based digitization and compression of video. Both IBM and Macintosh also provide machines with CD-ROM drives which support Kodak's Photo CD. Many machines also include a number of network access options. It is important first to know what your requirements are, and then to compare the available machines against your requirements.

However, if your faculty have not begun to use computers significantly in their own work, don't be surprised if they either aren't sure exactly what they would do with a computer in the classroom, or don't think they need one. "Technically inexperienced teacher-scholars who are asked what they want computers to do for them will at first respond only in terms of the computer's similarity to other tools and its applicability to tasks with which they are already familiar. Only when new possibilities are demonstrated to them in the conceptual framework of their own discipline will they begin to expand their own ideas as a basis for new uses; only after several passes through this learning cycle can they take the initiative in suggesting more complex research and teaching implementations." (Garrett, Dominguez, Noblitt, 1989) In other words, you may have to prime the pump. A word of caution, however: once the flow starts, you may not be able to stem it easily. A typical response to master classrooms at UNC-CH has been, "I really liked teaching my course in a master classroom. I was able to teach my classes in a way that was impossible before. But, you know what I'd really like to try is . . ." What they would really like to try inevitably requires additional equipment or an upgrade of some type. But then, that's how we know it's working!

Projecting the Right Image

Once you've made all these choices and you've decided on your computer system, the next decision point is matching the computer with an appropriate projection system. You have three options from which to choose, depending on a number of variables which we will examine. The three choices are video projection systems, LCD (liquid crystal display) panels used with an overhead projector, and a large screen television monitor. To help you evaluate the tradeoffs in these options, we will take a look at some of the basic differences between standard (NTSC) video and computer video, differences between cathode ray tube (CRT) video projection systems and LCD displays, and comparisons of front screen and rear screen projection.

TV and Computer Scanning Differences

The projection device is likely to be the single most expensive piece of equipment in your classroom. For this reason alone, you should choose it with care. But there's another good reason -- video projection compatibility with the computer is equally as important as compatibility between software and computer. And in some ways, it's harder to determine. Software and computers may not always speak the same language, but they operate in the same universe. Television and computers, on the other hand, come from

two different worlds: television is still primarily analog and computers are digital. Although both are capable of producing an image on something that looks like a television, the manner in which they do that is very different. In order to match your computer to the right projection device or television monitor, you have to know a little bit about the translation that's required between the two.

The language that video equipment speaks is usually NTSC composite video -- the standard for this country and many others. A standard video signal is composed of many elements. One of the most important for determining compatibility with computers is the scanning rate. Computer CRTs and video CRTs scan the image onto the screen in different manners. Video devices scan images by alternating lines of the picture, with the even-numbered lines creating one field (half the picture) and the odd-numbered lines creating the complementary field. These two fields are interlaced into one frame, or completed picture. On the other hand, higher resolution computer monitors typically scan images sequentially and in a non-interlaced manner.

These two different methods require different horizontal and vertical scanning rates in order to complete an image. There is usually more variance between the horizontal scanning rates than there is between vertical scanning rates of computers and video projection equipment. The higher the resolution of the signal transmitted by the computer, the greater the difference in horizontal scanning rates. Therefore, for DOS machines, different graphics adapter cards will require different scanning frequencies, too.

Generally, the higher the resolution of the signal generated by the computer, the higher the horizontal scanning rate will be -- and the higher the cost of the video projector required. So always confirm the compatibility of your computer's horizontal and vertical scanning rates with the projection system you plan to buy. Caveat emptor! (Table 3 shows the scanning frequencies for the most common PC graphics adapters and for the Macintosh. Note that the Commodore Amiga has a standard NTSC video output.)

There are several approaches to solving the compatibility problem if you have multiple requirements for computers, as we do at UNC-CH. The most convenient is to buy a multiscan video projector. Multiscan projectors accept a range of scanning frequencies, automatically detecting and locking onto the correct frequency for the computer. The exact range of frequencies supported varies with the manufacturer, the model and cost of the projector. Just make sure your computer's scanning frequencies are within the range supported by the projection unit. Strong performers in the current projection system market include Sony, Electrohome, NEC, Barco Electronics, Panasonic and Mitsubishi.

Often, an additional useful feature of multiscan projectors is the ability to display output from video equipment using the PAL or SECAM formats, which are more common in Asia and Europe. But if you plan to use your video projector with the newer component signal video equipment, be sure you specify those capabilities in your equipment requirements. Some video projectors do not have these capabilities. (Component video systems record the color part of the picture separately from the brightness part, as compared to standard video, which modulates the color signal on the luminance signal.)

Another method for using a computer with a projection unit having a lower scanning frequency is to use one of those ubiquitous "black boxes." In this case, these are called scan converters and are available for a variety of computer configurations and can be obtained from RGB Systems, Inc. When these boxes convert the computer's signal down to the video projector's acceptable frequency range, however, they lose the resolution and image quality inherent in the higher scanning frequencies of the computer.

Other Interface Factors

Other differences between video and computer signals that can affect the display include signal impedance and signal synchronization method (synch). Digital signals are usually of high impedance and can be

transmitted only 6 to 10 feet with consistent characteristics. Therefore, if you want to place your video projection system more than 6 to 10 feet from your computer, you will need an additional interface box, such as Extron's or Covid's, to get a good image.

Additionally, most video projection systems require an input signal that has composite synch and negative polarity. Digital signals usually have separate horizontal and vertical synch and their polarity may be negative or positive. Again, if your computer and projection system don't have compatible signals, you'll need an interface between them to convert the computer's output into an acceptable input signal for the projection system. A convenient solution for multiple requirements, available more recently, is the universal interface. The universal interface combines features found in a variety of individual interface boxes for different computers, and can accommodate higher resolution systems. For those wishing more detailed information about interfacing problems and requirements, an excellent interface manual, "The Handbook of Computer Interfacing," is available from Extron Electronics.

CRT vs. LCD

The most common form of fixed projection is still the CRT (cathode ray tube) type. But LCD (liquid crystal display) technology has created a newer projection system that provides some useful alternatives, especially for movable equipment configurations. CRT panels currently utilize two technologies: twisted nematic and active matrix. Active matrix is the newer technology and more often is used for color displays. Active matrix devices generally provide quicker response and higher contrast, as well. (Hallett, 1992) As usual, there are important tradeoffs between the two technologies. Here are some characteristics of the two display technologies, with their respective positives (+) and negatives (-) indicated:

CRT projection systems:
+ May accept wide range of computer scanning rates, including very high resolution input.
+ Project motion video more smoothly and with better resolution.
+ Project a large image.
+ Project a generally brighter image in large spaces or areas with more ambient light.
- Require convergence adjustments.
- Not designed for portability.

LCD projection systems:
+ Portable.
+ Relatively easy to set up.
+ Lower cost for applications without high definition or brightness requirements.
- Require an overhead transparency projector as a light source. [These projectors should produce 2,700 to 3,000 lumens of light, more than some cheaper models provide. (Griffin and Robison, 1992)]
- Some units may not display motion video smoothly. [Computer animation and full-motion video both require a pixel response time of less than 50 milliseconds. For other computer applications, the mouse pointer will disappear from the screen while you are moving it if the response time is greater than 75 milliseconds. (Griffin and Robison, 1992)]
- Not all units support NTSC video.

You can expect to see rapid improvements in both LCD and LCD active-matrix technologies. With their increasing sophistication have come increases in prices, although they are still generally cheaper than CRT video projection systems. But for now, the main advantage of LCD projectors is their portability. If you plan to use your projection system in only one setting, you'll get a better price/performance ratio from investing in a CRT system. On the other hand, if your situation requires using a display in many different rooms, the LCD will be much easier to transport and set up than bulkier projection systems requiring convergence.

Rear Projection vs. Front Projection

There are different advantages and drawbacks to rear and front projection methods. The chief advantages of rear projection are:
+ The ability to produce an adequate image in a room that contains a fair amount of ambient light.
+ The positioning of the teacher in front of the screen without being in the projection path.

Rear projection involves placing the projection equipment behind a frosted, translucent glass "screen." The projected image shines through the glass, creating an image on the frosted surface behind the teacher or presenter, with approximately a 50 degree viewing angle for the audience. The projection distance for creating an image of a given size is the same, whether you use front projection or rear. Therefore, if you use rear projection, you must either provide a sizable space behind the screen for the projection path, or you must provide special mirrors and lenses to create an equivalent projector throw length within a smaller space. Therein lie the major disadvantages of rear projection: "Rear screen is infinitely more expensive, demands good technical assistance, and demands a considerable additional area behind the screen or expensive special front coated mirrors and lenses." (Moldstad, unpublished) Rear projected images are also subject to "hot spots," concentrations of brightness in the image that appear in different places along the centerline of the screen, depending on the vantage point of the viewer.

An exception to most of the space and expense problems of rear projection systems is the one-piece rear projection, or retro-data, unit which looks like a very big console television. Since it is one-piece, it doesn't require as much additional space or projection mirrors. It is very bulky, however, and still has the viewing angle and resolution characteristics of rear screen projection.

In comparison to rear projection methods, front projection advantages are:
+ Higher image brightness and resolution.
+ Lower cost.
+ Potentially wider viewing angle, depending on the screen material used.
+ More even dispersion of light in the projected image.

In our applications at UNC-CH, we have used mostly front projection. Generally, we do not have the additional space, funds and staff support for large-scale rear projection use. Also, computer projections of text usually are sharper with front projection than with rear projection. The problem of the instructor blocking the projection path for front projection can normally be controlled by mounting the projector on the ceiling. This also keeps the projector out of the way of most beverages or other snacks that may occasionally find their way into the classroom, curious students who may fiddle with the controls, and thieves with well-developed biceps. Newer projection units require less frequent alignments and may have remote controls that prevent your having to climb ladders to make the alignments after initial installation.

Displays for Smaller Classrooms

In some cases your classroom may be so small that you don't need or want to use a video projector. In cases where a direct-view television/monitor will suffice, here are a few guidelines for the number of viewers per monitor and their distance from it. (Note that the same considerations regarding scanning frequencies must be considered for televisions/monitors as for video projectors.)

In general, a television or monitor can accommodate in its upper range one viewer for each inch of its diagonal screen measurement. That is, a 25-inch monitor is sufficient for approximately 25 viewers. If your classes are no larger than two or three students, you should still have at least a 25-inch monitor. This assumes that the viewers are seated within a 45 degree angle of the monitor centerline and that they are at

least four screen widths away. The ideal viewing distance would be about 6 1/2 screen widths away. The maximum viewing distance for monitors, as well as projectors, depends on the legibility of the projected image to the most distant viewer, given reasonable brightness and definition. Direct-view monitors have brighter displays with better contrast than any other display medium. However, it is not cost-effective to make an extremely large direct-view monitor that can provide as large a viewing area as projection systems with image diagonals up to 100 and 200 inches. Due to this inherent image size limitation, direct-view monitors are primarily useful for moderately small classrooms.

LCD panels are also useful for smaller rooms where ambient light is not a problem. If you are using the LCD panel to project NTSC video from a videocassette player, network, etc., you must make sure that the LCD panel handles motion video adequately. As mentioned earlier, the pixel response time for the panel must be less than 50 milliseconds to project motion video adequately. (Griffin and Robison, 1992) The panel must also accept connectors for the appropriate video devices.

Subjective Evaluation Tips

Whatever your projection system, be sure to check its image quality with both text and graphics, as well as a variety of software and regular video inputs to make sure your viewing conditions are suitable for the type of information you intend to present. Text in the corners should look as focused as it does in the center. Both black and white text letters should be equally clear and readable. Neither the darkest nor the lightest colors should be washed out, and gray colors should not be tinted with other colors. (Ripp, 1990) Signals from different computers also look different even when displayed by the same projector, so you should always make sure you have tested the projector/monitor with the computer(s) you plan to use, as well as with a representative sample of the software and fonts you intend to use.

Other Projection Factors

Brightness

Other important factors in projecting an acceptable image from a computer are projector brightness, convergence type and screen type. Brightness is expressed in lumens and can be a critical factor in the legibility of the projected image -- especially in rooms where ambient light cannot be controlled easily and/or room lights cannot be dimmed. In fact, for other than the most expensive units, room lights have to be dimmed somewhat for adequate viewing of any video projector. Brightness of video projection systems is rated in many ways and the raw figures do not always correlate with the perceived image in the same manner. It's best if you can test the projector in your space or in conditions as close to yours as possible. There is a down side to brightness, too. As the brightness increases, the sharpness and contrast of the projected image decrease. You may have to evaluate the projected image subjectively, taking into account the tradeoff between these characteristics.

Note: There is a new standard for rating lumens output for projection devices. This rating method was created by ANSI, a national standards body, to provide a consistent and uniform means of testing lumen output. These ANSI ratings are a reliable and objective means of comparison of brightness. When the lumen rating method is listed as "CRT," or is unlisted, you cannot make objective brightness comparisons between different units based on these ratings.

Convergence Type

Another consideration for video projector selection is convergence type. Projectors with three color tubes have either fixed or variable convergence lengths. This means that the transmissions from the three color tubes either converge only at a fixed distance from the screen, or the convergence distance can be varied,

making it possible to move the projector closer to, or farther away from the screen. Moving the projector in either direction makes the projected image either smaller or larger. If your projector has fixed convergence, you can't vary the distance, therefore you cannot vary the image size.

Screens

The selection of a projection screen can affect the perceived brightness of the image, as well as the acceptable viewing angle and resolution. In general, for a given projection, the wider the viewing angle, the darker the image. Room configuration, in conjunction with image size and screen viewing angle, determine how many students can sit within a given space and comfortably see the projected image. A handy tool for manipulating these variables is the "Kodak Projection Calculator and Seating Guide" (Kodak publication No. S-16, Catalog #107-8989).

Matte screens (or a smooth plastered white wall) disperse light more evenly throughout the room, and have the widest viewing angle (up to 90 degrees), but they also yield the dimmest image. These characteristics make matte screens good for applications where you need a wide viewing angle, or require close viewing with greater image sharpness and quality. (This would be the case, incidentally, with high definition television images, which can be viewed from a shorter viewing distance than standard resolution video.)

Lenticular screens and glass-beaded screens reflect more light, giving a brighter image, but creating a narrower viewing angle (approximately 60 degrees). Rigid foil-covered screens are extremely reflective, but the images disappear as you move outside the 50 degree viewing angle. Beaded screens are useful in relatively narrow rooms, but not in large auditorium situations which may require wider viewing angles. Lenticular and rigid foil-covered screens are best suited to smaller rooms with a narrower viewing area and, especially such rooms in which it is difficult to control the ambient light.

Most manufacturers also offer screens with a special surface, called "Spectra Surface," that is designed specifically for use with LCD panels. Because of the specially treated surface, this screen increases the brightness of the image, but it is limited to a viewing angle of no more than 30 to 45 degrees off the perpendicular. (Griffin and Robison, 1992)

Screen Size and Distance from the Viewer

To determine the appropriate screen size for optimum viewing in your classroom, divide the distance from the screen to the farthest viewer by six. The closest viewers should be no closer than 1 1/2 to 2 times the screen width. The most distant student should be no more than six widths away.

Control Systems for the Classroom

Integrated control systems can simplify the operation of a master classroom and reduce the confusion faculty members may feel when confronted with the multiple options and controls for a cabinet full of equipment. Without an integrated control system, you will need to provide a variety of remote control devices for the various projectors (slide, 16mm and video), as well as for the videocassette player and possibly for the audio. Needless to say, without a custom control system, simple but thorough written instructions and a hands-on demonstration are also essential for faculty before they teach in the master classroom.

At UNC-CH we are currently retrofitting our master classrooms with AMX control systems. The AMX system is software-controlled, but independent of the computer in the classroom. Using the SX EL Touch Panel, in conjunction with wired or wireless remote controls, the teacher can control all the equipment (and the room lights and electric screen, if desired). The control device is software-configurable, so general

controls can be programmed for the entire system, or individual screens can be designed for a particular teacher's needs. In the latter instance, the instructor only has to call up his or her control screen and can avoid the clutter of controls for unnecessary functions.

Another method is to use the microcomputer itself as a control device. Then, instead of having to read and master instructions for all the equipment in the room, the instructor only has to be able to power up the computer and select the functions he/she requires from the computer menu or icons. This would require some rather complex programming, however, including drivers for each of the equipment types. Some schools, such as Indiana University-Purdue University at Indianapolis(IUPUI) have developed their own systems to do this. At IUPUI, Dr. Ali Jafari and his staff at the Integrated Technologies Laboratory developed the TAG3 system to control all room technology functions and to provide a Knowledge-Based Help System that automatically pages a technician when help is required. (Jafari, 1992) This system is now being marketed by Extron.

In addition to the AMX systems, control systems such as the Video Director and Crestron's customized control systems are available commercially.

Networking Information Sources

To fully utilize the master classroom's capabilities, it should be networked to a variety of media and resources. This necessitates connecting your master classroom to building and departmental LANs (local area networks) as well as to your campus network. The following is a description of some of UNC-CH's objectives in networking classrooms for data communication:

"A related objective is to provide instructors with classroom access to exactly the same software, data and menus that students will use in the laboratory, without having to maintain duplicate copies in the classroom. From a faculty and student perspective, using a network service is as simple as choosing a menu option to use a software package or request a connection to a mainframe computer. For personal computer service, a file server directory in a remote location appears to the local user as another disk drive . . . These remote disk services provide transparent connectivity." (Hazen and Parker, 1989)

The connections between lab networks, department networks and classrooms are implemented with Novell network software running over Ethernet channels on the campus network. When our fiber optic network is installed this year we will move to FDDI as a transitionary strategy while ATM equipment standards are being developed.

Via the campus network, the master classrooms are also connected to several video sources. This allows faculty to receive SCOLA foreign language newscasts and NASA space flight coverage from our satellite downlink, as well as other satellite conferences. Our Nonprint Materials Collection can transmit videocassette and film material from their collection to the classroom. And master classrooms can receive classes and conferences originated on the CoNCert two-way video microwave network connecting us with 10 other universities and two research institutes in the state.

Cost Considerations

Support Requirements

An important element in supporting a master classroom is realizing that faculty may be dependent on the equipment and communications systems' unique capabilities to teach a particular concept, unit or the entire course. There may not be an alternate method for teaching the material; class cannot always continue when there is equipment failure. Therefore, to avoid inconveniencing faculty and canceling classes, functional

problems need to be addressed quickly.

Your support requirements will vary depending on the number of master classrooms you are maintaining and their intensity and scope of use. We currently have 14 master classrooms at UNC-CH, in addition to a number of other specialized facilities such as computer classrooms, teleclass-rooms (two-way video and audio capable) and media intensive classrooms. Eleven of the master classrooms are scheduled by courses on a semester basis. Three of them are scheduled on an "as needed" basis to accommodate courses which need their capabilities, but for a short period of time.

To help support these facilities we operate the Classroom Hotline, a special telephone line dedicated to use by faculty for scheduling equipment and facilities or reporting problems with any aspect of classroom use. Operational problems with master classrooms are reported via the hotline and one of our graduate student staff responds to correct the problem. When the problem exceeds a student's expertise, the student calls on our electronic technician for help. When the problem cannot be corrected immediately, we try to replace the faulty equipment temporarily with a spare unit. For hardware repair, a rule-of-thumb for budgeting supplies and parts is usually five percent of your hardware cost.

If you provide the software for your classroom, rather than having individual faculty or departments provide it, you will have some additional costs. These include purchase of individual and/or network licensed software, replacements and upgrades. Don't forget that applications software upgrades may not remain compatible with your systems software and firmware (graphics and video adapter cards, video compression, etc.) or memory and hard disk requirements. Before you upgrade any software, make sure you know whether it is downwardly compatible, or you may find yourself with a more expensive upgrade than you had planned.

Dollars and Sense

Classroom construction and renovation costs vary widely depending on the circumstances, but if you are starting out with a classroom in generally good condition, your renovation costs should be minimal. Networking costs are also situational, depending on whether there is an existing network with building distribution, the type of existing networking medium (wiring) and the network interfaces and software required to communicate over it. These factors are too variable to make any generalizations about cost.

Equipment costs for a master classroom, on the other hand, are rather predictable. Since they vary little with seating capacity (only the projector image and screen size change with room size), they differ little from room to room. The equipment (including control interface) currently costs about $35,000 - $40,000, assuming state contract prices and/or an educational discount. While this cost is not trivial to most educational institutions, it is about 1/10 the cost of the typical computer lab/classroom. Therefore, master classrooms are a relatively cost-effective means of integrating computing and communications power into the classroom. Their cost-effectiveness can be further enhanced if they are restricted to use by courses which require computer- or communications-intensive applications. In other words, you wouldn't schedule a course in a master classroom for the semester if the instructor intended to use only the overhead transparency projector!

Conclusion

In our experience at UNC-CH, master classrooms have been heavily used by a variety of departments and schools. These include English; Radio, Television and Motion Pictures; Chemistry; Mathematics; Psychology; Folklore; Library and Information Science; Education; History; Speech Communications; Pharmacy; Economics and Political Science. Faculty members continue to find new applications for the technology and challenge us to enhance the master classroom's capabilities. Their requests and "what ifs"

have led to many improvements and to the development of even more specialized facilities.

Because many faculty wanted to extend their use of the computer in the classroom so that students could participate in hands-on applications, we developed a computer classroom. In addition to an instructor's workstation, this classroom has 21 networked IBM PS/2 student workstations, all capable of operating in both MS-DOS and the Microsoft Windows environment. The computer classroom also contains all the other media and communications capabilities of a master classroom.

As digitized video and other multimedia technologies continue to develop, we will continue integrating these new capabilities into the master classroom. CD-ROMs hold the potential for providing a new standard for academic courseware and publishing. New products, such as the Photo CD from Kodak, present new options for high density storage, random access and rapid retrieval. These are both supported by the current equipment configuration described in this document. But ever newer products and technologies will evolve, and with them the scope and sophistication of the master classroom will evolve, too.

All these technologies provide interesting possibilities for the future, but we still see the master classroom as the primary means of putting technology into the mainstream of today's instructional activity. We are continuing to develop one or two additional master classrooms each year; our goal is to provide a small, medium and large capacity master classroom for each academic building. Changing technology will definitely alter the design and function of our classrooms as we pursue this goal. And undoubtedly our vision and goals will change along the way. But we think the master classroom is a reasonable starting point for creating an information environment for teaching in the classroom.

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About the Author

Kathryn is currently Senior Analyst for Distributed Learning Environments with the Institute for Academic

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Additional Sources of Information on Classroom Design

- VIDEOTAPE - "Classroom Design with Technology in Mind" 2/94 Broadcast
- Computer Classroom and Laboratory Design: Bibliography
- Assessments of Multimedia Technology in Education: Bibliography

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